

Import Geometrics Plotrefra .VS & Remove trigger jitter & Smooth invert marine refraction profile L-230\_VS v. 5.01 :

Fig. 1 : Top : *Trace/Shot gather*. Bottom : *Refractor/Shot breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed colored curves, blue crosses). Green dots are your reciprocal picks.

## To create the profile database, import the data and browse the imported shots do these steps :

- File New Profile..., set File name to L-230\_vs and click Save button
- in the prompt shown next (Fig. 4) click *No* button to determine *Profile start* / first receiver station number by dividing the first receiver position in the .VS file by our *Station spacing* (Fig. 2)
- in *Header*|*Profile*... select *Line type* Refraction spread/line . Set *Station spacing* to 0.5 m. See Fig. 2.
- in *Header* |*Profile*... check box *Force grid cell size* and set field *Cell size* [*m*] to 0.5m (Fig. 2)
- in *Header*|*Profile*... check box *Extrapolate tomograms* and set field *Extrapolate [station spacings]* to 30. See Fig. 2.
- unzip archive <u>https://rayfract.com/tutorials/L-230\_VS.zip</u> containing file L-230\_fixed.VS in directory C:\RAY32\L-230\_VS\INPUT
- select File Import Data ... and set Import data type to Geometrics Plotrefa .vs. See Fig. 3.
- click Select button and navigate into C:\RAY32\L-230\_VS\INPUT
- select file L-230\_fixed.vs & click Open
- leave Default spread type at 10: 360 channels
- click *Import shots button*.
- in our *Import shot* dialog leave *Layout start [station no.]* and *Shot pos. [station no.]* as displayed for each shot. Just click *Read button* to import the shot. Click *Read* button repeatedly to import all 54 shots displayed.
- select *TracelShot gather* to obtain Fig. 1
- click on title bar of *Refractor*|*Shot breaks* window (Fig. 1 bottom) and press ALT+P. Edit *Maximum time* to 70 ms & press ENTER key to redisplay. Do the same for *Trace*|*Shot gather* window (Fig. 1 top).
- browse shots in *TracelShot gather* window with F7/F8 (Fig. 1 top)
- select *Processing menu* item *Remove trigger jitter for all shots*

#### Run default fail-safe Smooth inversion with 1D-gradient laterally averaged starting model :

- check option Grid|Receiver station ticks on top axis
- check option Grid|CS\_CENTERED font for shot points and receivers
- edit Grid|Surfer plot Limits as in Fig. 8
- select Model WDVS Smoothing and click radio button restore WET smoothing and discard WDVS smoothing only. Leave box use WDVS for forward modeling of traveltimes unchecked (Fig. 9).
- uncheck blanking option WET Tomo|Blank|Blank below envelope after last iteration
- select Smooth invert|WET with 1D-gradient initial model
- dismiss prompt *Shot point spacing is much too wide* (Fig. 11). This prompt is not relevant for marine refraction data recorded at continuous incremental positions with towed streamer.
- wait for the 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 6 & 7

Edit Profile					
Line ID E	230_VS	/line	<b>_</b>	Time of Date	of Acquisition
Instrument Client Company Observer				Time of Date Time Units	of Processing
Note			*	Sort Const	As acquired 🗨
Station spacing (r Min. horizontal se Profile start offset	n] paration [%] [m]	9.0 9.0 0	25 .0000	Left	thanded coordinates
Force grid	cell size		Cell si	ze [m]	0.5000
First receiver [st:	er station numb	er for profi	0	Foi	rce first receiver
Extrapolate starting models and WET tomograms Extrapolate [station spacings] 30 🔽 Extrapolate tomograms				rapolate tomograms	
Add borehole lir Borehole 1 line Borehole 2 line	Select	ography-			
Borehole 3 line Borehole 4 line	Select Select				
ОК	Cancel	R	eset		

Fig. 2 : Header/Profile

Force first receiver at station number 1?

Import shots					
Import data type	Geometrics Plotrefa .VS	•			
Input directory : select one data file. All data files will be imported					
Select C:\RAY32\L-230_VS\INPUT\					
Take shot record number from	Record number	•			
Optionally select .HDR batch fil	Optionally select HDR batch file and check Batch import				
.HDR batch					
Write .HDR batch file listing sho	ts in input directory				
Output .HDR					
Write .HDR only	Import shots and write .HDR				
Overwrite existing shot data	- Ratah impart				
Overwrite all     O Prompt	Overwrite all     O Prompt overwriting     Limit offset				
Maximum offset imported [station	nos.] 1000.00				
Default shot hole depth [m]	Default spread type				
0.00	10: 360 channels	-			
Target Sample Format	16-bit fixed point				
Turn around spread during in	nport 📃 Reverted spread layo	out			
Correct picks for delay time (	use e.g. for .PIK files)				
Default sample interval [msec]	0.100000000 Force sample in	nterval			
Default sample count	20000 Force sample of	ount			
Import shots	ancel import <u>R</u> eset import				

Fig. 3 : File/Import Data

Do you want to force the first receiver at station number 1 for this new profile ? Click 'Yes' button to confirm. Click 'No' button if the first receiver is at station number 0. If you confirm with 'Yes' then we will force the first receiver station to 1 in HeaderlProfile dialog For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click 'No' button. For multi-spread profiles click 'No' button and use our .HDR batch import options in File/Import Data dialog to generate the HDR file. Next edit the .HDR file using Notepad editor with corrected station numbers for Layout start and Shot pos. for all shots. Next use the edited .HDR batch file for import of all shots. For vertical borehole spread/line profiles click 'No' button. The first receiver station will be set to station number of deepest receiver (elevation divided by Station spacing) during import. No Yes

Fig. 4 : click *No* button to determine the first receiver station number for this profile from the Geometrics Plotrefa .VS by dividing the first receiver position in the .VS file by our *Header/Profile/Station spacing* (Fig. 2).

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button. For multi-spread profiles click No button and use our .HDR batch import options in *File/Import Data* dialog to generate the .HDR file. Next edit the .HDR file using MS Notepad editor with corrected station numbers for *Layout start* and *Shot pos.* for all shots. Next use the edited .HDR batch file for import of all shots.





Fig. 5 : 1D-gradient starting model obtained with Smooth invert/WET with 1D-gradient initial model.



L-230\_VS RMS error 0.8%=0.44ms 20 WET itr. 50Hz Width 3.5% initial GRADIENT.GRD v. 5.01

Fig. 6 : 2D WET output obtained with *Smooth invert/WET with 1D-gradient initial model* & starting model shown in Fig. 5. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Don't discard WET smoothing after forward modeling. Leave WDVS disabled (Fig. 9).



Fig. 7 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per grid cell.

Edit Surfer plot limits	
Plot Limits           Plot Limits         OK           Image: Plot limits active         Image: Plot limits           Image: Plot limits active         Image: Plot limits	Fig. 8 (left) : Grid/Surfer plot Limits dialog .
Max. offset     1722.250     [m]     Reset       Min. elevation     -40.000     [m]     Reset to grid       Max. elevation     3.000     [m]     Redisplay grid       Min. velocity     1400     [m/sec.]       Max. velocity     5000     [m/sec.]	Edit WDVS (Zelt & Chen 2016)         Edit parameters for wavelength-dependent velocity smoothing         use WDVS for forward modeling of traveltimes         fast WDVS : less accurate mapping of scan line nodes to grid nodes         add nodes once only with overlapping scan lines for velocity averaging         add all velocity nodes within WDVS area with radius of one wavelength
Plot Scale         Proportional XY Scaling         Page unit centimeter. Uncheck for inch.         X Scale length       6.000 [inch]         Y Scale length       3.000 [inch]	□ pad WDVS area border with one grid cell         WDVS frequency       300.00       [Hz]         Angle increment between scan lines       7       [Degree]         Regard nth node along scan line       3       [node]
Color Scale         I✓       Adapt color scale         Scale height       3.125 [inch]         Velocity interval       200 [m/sec.]         Coverage interval       5 [paths/pixel]         Receiver labeling       -236 [station no.]	Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)         a : Cosine argument power       1.000       [power]         b : Cosine-Squared power       1.000       [power]         Modify WET smoothing mode : discard after forward modeling
Station interval 100 [station no.]  Use station index or station no. offset	Fig. 9 : <i>Model/WDVS Smoothing</i> dialog .

Edit parameters for reciprocal error file (Jim Whiteley 2020)				
Select output .ERR file Select error file C:\RAY32\L-230_VS\RECIPROCAL.ERR				
Sort lines in .ERR file by decreasing reciprocal error C Sort .ERR lines by relative reciprocal error Sort .ERR lines by absolute reciprocal error in ms Sort .ERR lines by offset and CMP (as in Trace Offset gather display)				
CMP interval for mapping common-offset sorted traces to same midpoint         Reciprocal CMP interval       100.0       [station no.] to search for reciprocal traces         Export to .ERR       Cancel       Reset				

Fig. 10 : Trace/Export reciprocal errors and update database

# Plot your reciprocal traveltime picks on shot-sorted trace gathers :

Plotting your reciprocal traveltime picks on shot-sorted trace gathers lets you quality-control your first break picks and check the validity of your recording geometry specification (shot station numbers and receiver station numbers) :

- > select *Trace*|*Export reciprocal traveltime picks and update database*
- click button Select error file and click Save button (Fig. 10)
- ➢ set field Reciprocal CMP interval [station no.] to 100.0 (Fig. 10)
- click button Export to .ERR
- > optionally check new option *TracelOpen RefractorlShot CMP breaks with Shot gather*
- ▶ select *Trace*|*Shot gather* to obtain a window display as in our Fig. 1
- > check new version 4.05 option *DisplaylShow reciprocal picks on Shot Gather*
- ▶ browse and zoom trace gathers with function keys F7/F8, F1/F2 etc. as usual
- navigate traces with arrow-left and arrow-right keys
- if a reciprocal pick was determined and matched to the current trace then this is plotted as a green dot on the trace
- also we show Reciprocal Shot/Channel and Reciprocal offset[m]/CMP in status bar at bottom of application window (Fig. 1 bottom) if a reciprocal pick is available in the .ERR file



Fig. 11 : Dismiss this prompt with OK button. This prompt is not relevant for marine refraction data recorded at continuous incremental positions with towed streamer.

Here is the link to the .RAR archive with the L-320\_VS profile folder for above Fig. 6 :

https://www.dropbox.com/scl/fi/62lohzw5wqnxofmof6wh8/L-230 VS Nov21 2024.rar?rlkey=fgg2ll0na3r52qkod1wtroo1a&st=rc2wepds&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

## Automatic DeltatV and interactive WET inversion

Next we show *Automatic DeltatV* inversion to obtain our pseudo-2D DeltatV initial model. We enable DeltatV option *Suppress velocity artefacts*. Then we use the DeltatV starting model grid DELTATV.GRD for interactive WET inversion using *minimal WET smoothing*. Also we lower the *WET wavepath frequency* from default 50Hz to 20Hz. We increase the *WET wavepath width* from default 3.5 percent to 10 percent :

- check option DeltatV\Deltat Settings\Suppress velocity artefacts . See Fig. 12.
- select DeltatV\Automatic DeltatV and WET inversion
- ➢ confirm prompt to obtain the pseudo-2D DeltatV starting model. See Fig. 14.
- ▶ when prompted to continue with WET inversion click *No* button
- select Model Forward model traveltimes and C:\Ray32\L-230\_VS\TOMO\DELTATV.GRD
- ▶ select Grid Image and contour velocity and C:\Ray32\L-230\_VS\TOMO\DELTATV.GRD to get Fig. 14
- ➢ select WET TomolInteractive WET and edit main dialog as in Fig. 13 (left)
- click button *Edit velocity smoothing* and check radio button *Minimal smoothing* (Fig. 13 at right)
- click buttons Accept parameters and Start tomography processing (Fig. 13) to obtain Fig. 15 and 16

L				
	Output Measured CMP Velocities			
$\checkmark$	Output Horizontal offset of CMP pos. in meters			
	Output DeltatV results in Eeet			
_	Allow regression over two CMP traces			
$\checkmark$	CMP is zero time trace			
$\checkmark$	Reduced offset 0.0 is valid trace with time 0.0			
	Enforce Monotonically increasing layer bottom velocity			
$\checkmark$	Suppress velocity artefacts			
	Process every CMP offset			
✓	Prefer Average over minimum interface velocity			
	Taper velocity steps at layer interfaces			
	Smooth CMP traveltime curves			
✓	Weigh picks in CMP curves			
	Extrapolate output to all receivers			
	Regard mapping for shot offset correction			
	Regard true receiver coordinates for shot offset correction			
	Regard 3D source-receiver offset for all traces			
	Extrapolate tomogram over 30 station spacings			
	Extra-large cell size			
	Increase cell size			
	Decrease cell size			
	Extra-small cell size			
$\checkmark$	Edit cell size			
	Limit DeltatV velocity exported to maximum <u>1</u> D-gradient velocity			
	Limit DeltatV velocity exported to 5,000 m/s			
	Write new DeltatV settings to .PAR file			
	Reset DeltatV settings to default			
	Reset DeltatV and WET and WDVS settings to .PAR file			

Fig. 12 : check option *Supress velocity artefacts* in *DeltatV/DeltatV Settings* menu. Leave all other DeltatV settings at their default setting.

Edit WET Wavepath Eikonal Traveltime Tomography Parame	Edit WET Tomography Velocity Smoothing Parameters	
Specify initial velocity model	Determination of smoothing filter dimensions	
Select C:\RAY32\L-230_V	S\TOMO\DELTATV.GRD	C Full smoothing after each tomography iteration
Stop WET inversion after		Minimal smoothing after each tomography iteration
Number of WET tomography iterations : 20	) iterations	Manual specification of smoothing filter, see below
or RMS error gets below 2.0	) percent	Smoothing filter dimensions
or RMS error does not improve for n = 20	) iterations	Half smoothing filter width : 16 columns
or WET inversion runs longer than 100	) minutes	Half smoothing filter height : 0 grid rows
		Suppress artefacts below steep topography
WET regularization settings 20.00	Hz Iterate	Adapt shape of filter. Uncheck for better resolution.
Ricker differentiation [-1:Gaussian2:Cosine] :	times	Maximum relative velocity update after each iteration
Wavepath width [percent of one period] : 10.0	percent Iterate	Maximum velocity update : 25.00 percent
Wavepath envelope width [% of period] : 0.0	) percent	Smooth offer each ath iteration only
Min velocity 10 Max velocity 6000	) m/sec	Smooth nth iteration : n = 1 iterations
Width of Gaussian for one period (SD)	, sigma	
	Smoothing filter weighting	
Gradient search method		
Steepest Descent     Conjugate	Gradient	Used width of Gaussian
Conjugate Gradient Parameters		Uniform central row weight 1.0 [1100]
CG iterations 10 Line Search iters.	2	Smooth velocity update before updating tomogram
Tolerance 0.001 Line Search tol. 0.0010		Smooth update Smooth nth 🔽 Smooth last
Initial step 0.10 Steenest Descent step		Damping of tomogram with previous iteration tomogram
	Damping (0, 1) 0,000 Damp before smoothing	
Edit velocity smoothing Edit grid file ge		
Start tomography processing Reset	<u>C</u> ancel	Accept parameters Reset parameters

Fig. 13 : WET Tomo/Interactive WET with DeltatV starting model. Edit main dialog as shown at left. Click button Edit velocity smoothing and edit velocity smoothing as shown at right. Click buttons Accept parameters and Start tomography processing to obtain Fig. 15 and 16.







3000 2800



-20







Fig. 16 : WET wavepath coverage plot obtained with Fig. 15. Unit is wavepaths per grid cell.

When comparing Fig. 6 (Smooth invert using 1D-gradient starting model) with Fig. 15 using pseudo-2D DeltatV starting model :

- note the lower velocities at bottom of the WET tomogram in Fig. 15 than in Fig. 6  $\triangleright$
- also note the good match of lateral velocity variation between Fig. 6 and Fig. 15 down to 20m below  $\triangleright$ topography. At greater depths Fig. 15 shows stronger lateral velocity variation than Fig. 6.
- $\triangleright$ the RMS misfit for Fig. 15 at 0.46ms is almost as low as for Fig. 6 at 0.44ms
- ≻ also the RMS error for the pseudo-2D DeltatV starting model is really low already at 0.69 ms (Fig. 14)

Here is the link to the .RAR archive with the L-320\_VS profile folder for above Fig. 15 :

https://www.dropbox.com/scl/fi/7dwu98z4a1vovwn4zwtl8/L-230 VS Nov23 2024 DeltatV and WET.rar?rlkey=j5erbeebat4crvanxany2pcxp&st=v415nmht&dl=0

If you know the bathymetry (sea-floor elevation) along the profile then you can use our *WET TomoWET velocity constraints* dialog to blank the water layer with a Surfer .BLN blanking file and a blanking velocity of 1,500 m/s. See our earlier marine refraction tutorial <u>https://rayfract.com/tutorials/SR6.pdf</u>.

#### **Obtain layered refraction starting model using our CMP Intercept-Time refraction method :**

Next we show layered refraction interpretation with our CMP Intercept-Time refraction method and using this as starting model for interactive WET inversion :





Frace to refractor mapping parameters			
Processing Option	IS		
Direct wave first breaks recorded			
Update branch points with Plus-Minus			
Velocity Determina	ation Parameters –		
Refractor Count [1	or 2]	2	
CMP Stack Width	[CMPs]	500	
Regression Receiver Count 3			
Direct Wave Delta	30		
Refracted Wave Offset Delta 50			
Specify Upper Layer Velocity Limits [m/sec.]			
Weathering F	Refractor 1 Re	fractor 2	
1600	2300	7000	
Median Layer Velocities Detected [m/sec.]			
1570	1071	0254	
1 1570	1071	2354	
Shot & Receiver spacing [stations], CMPs/Recvr			
60.1	1.0	2.8	
Map traces	Reset	Cancel	

Fig. 18 : press ALT+M in *Refractor/Midpoint breaks*. Edit as shown and click *Map traces*.

Crossover distance smoothing			
Crossover distance smoothing			
Overburden filter [station nos.]	300		
Basement filter [station nos.]	200		
Offset limit basement coverage			
Offset limit [station nos.]	20		
<u>A</u> ccept <u>R</u> eset	Cancel		

Fig. 19 : press ALT+G. Edit crossover smoothing parameters as shown. Click *Accept* button.



Fig. 20 : select *Depth/CMP Intercept-Time Refraction*. When prompted to continue with WET inversion click No button. Click on title bar of CMP Depth Section window. Press ALT+M and edit CMP Model Parameters as shown. Click OK.

- select Refractor Midpoint breaks (Fig. 17)
- > press ALT+M and edit mapping parameters (Fig. 18) and click button Map traces
- > press ALT+G to edit the Crossover smoothing (Fig. 19). Edit as shown and click Accept button.
- select Depth|CMP Intercept-Time Refraction
- confirm warning prompt about artefacts to obtain layered refraction starting model (Fig. 20 and 21)
- when prompted to continue with WET inversion click No button. Redo mapping in Fig.17/18/19.
- ▶ reselect Depth|CMP Intercept-Time Refraction. Click on title bar of CMP Depth Section window.
- > press ALT+M and edit CMP Model Parameters as shown in Fig. 20
- click OK button to obtain updated Fig. 20 and Fig. 21



Fig. 21 : select *Depth/CMP Intercept-Time Refraction* after mapping traces to refractors (Fig. 17/18/19). When prompted to continue with WET inversion click No button. Redo mapping in Fig. 17/18/19. Reselect *Depth/CMP Intercept-Time Refraction*. Press ALT+M and edit CMP Model Parameters (Fig. 20) and click OK button to obtain our CMP Intercept-Time refraction starting model.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters
Specify initial velocity model C:\RAY32\L-230_VS\LAYRTOMO\CMPMODL.GRD	Determination of smoothing filter dimensions     Full smoothing after each tomography iteration     Minimal smoothing after each tomography iteration     Manual specification of smoothing filter, see below
Stop WET inversion after Number of WET tomography iterations : 20 iterations	
or RMS error gets below     20     percent       or RMS error does not improve for n =     20     iterations	- Smoothing filter dimensions Half smoothing filter width : 16 columns Half smoothing filter height : 0 arid rows
or WET inversion runs longer than     100 minutes       WET regularization settings     20.00	Suppress artefacts below steep topography     ✓ Adapt shape of filter. Uncheck for better resolution.
Wavepan mequency:     20.00     Hz     Iterate       Ricker differentiation [-1:Gaussian,-2:Cosine]:     -1     times       Wavepath width [percent of one period]:     10.0     percent     Iterate	Maximum relative velocity update after each iteration Maximum velocity update : 25.00 percent
Wavepath envelope width [% of period] :       0.0       percent         Min. velocity :       10       Max. velocity :       6000       m/sec.	-Smooth after each nth iteration only Smooth nth iteration : n = 1 iterations
Width of Gaussian for one period [SD]:     3.0     sigma       Gradient search method     Sigma     Sigma	─Smoothing filter weighting C Gaussian
Steepest Descent     Conjugate Gradient     Conjugate Gradient	Used width of Gaussian 1.0 [SD] Uniform central row weight 1.0 [1100]
CG iterations     10     Line Search iters.     2       Tolerance     0.001     Line Search tol.     0.0010	Smooth velocity update before updating tomogram
Edit velocity smoothing     Edit grid file generation	Damping [01] 0.000 Damp before smoothing
Start tomography processing Reset Cancel	Accept parameters Reset parameters

#### Run interactive WET inversion using our CMP Intercept-Time Refraction starting model :

- ▶ select *Model*|*WDVS Smoothing*. Edit as in Fig. 9 and click *OK* button.
- > select WET Tomo|Interactive WET (Fig. 22 left). Edit main dialog as shown.
- > click button *Edit velocity smoothing* and edit as in Fig. 22 at right.
- click buttons Accept parameters and Start tomography processing (Fig. 22) to obtain Fig. 24 & 25

Fig. 22 : select WET Tomo/Interactive WET to display WET main dialog and edit as shown (left). Edit velocity smoothing (right). Click buttons Accept parameters and Start tomography processing to obtain Fig. 24 and 25.

L-230\_VS RMS error 0.8%=0.46ms 20 WET itr. 20Hz Width 10.0% initial DELTATV.GRD v. 5.01



Fig. 23 : same as Fig. 15. WET Tomo/Interactive WET (Fig. 13) with DeltatV starting model (Fig. 14). WET frequency 20Hz. WET wavepath width 10 percent. Minimal WET smoothing. Don't discard WET smoothing (Fig. 9). Leave WDVS smoothing disabled (Fig. 9).



L-230\_VS RMS error 0.8%=0.46ms 20 WET itr. 20Hz Width 10.0% initial CMPMODL.GRD v. 5.01

Fig. 24 : 20 Steepest-Descent WET iterations. Starting model is Fig. 21. Don't discard WET smoothing after forward modeling. WDVS disabled (Fig. 9). Minimal WET smoothing (Fig. 22 right). WET wavepath frequency 20Hz. WET wavepath width 10 percent. Ricker differentiation -1 [Gaussian]. Max. WET velocity 6,000 m/s (Fig. 22 left).



We compare Fig. 23 using DeltatV starting model with Fig. 24 using CMP Intercept-Time starting model :

- > note the lower velocities at bottom of the WET tomogram in Fig. 24 than in Fig. 23
- good match of lateral velocity variation between Fig. 24 and Fig. 23 down to 35m below topography.
- ▶ the RMS misfit for Fig. 24 at 0.46ms is just as low as for Fig. 23 at 0.46ms
- > the RMS error for the CMP Intercept-Time starting model is really low already at 0.64 ms (Fig. 21)

Here is the link to the .RAR archive with the L-320\_VS profile folder for above Fig. 24 :

https://www.dropbox.com/scl/fi/ov0xqpghi266sddhcwjpk/L-230 VS Nov24 2024 CMPIntercept and WET.rar?rlkey=0lmluphtpp8gks3wqz3fwomqu&st=54ldn9ru& dl=0

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